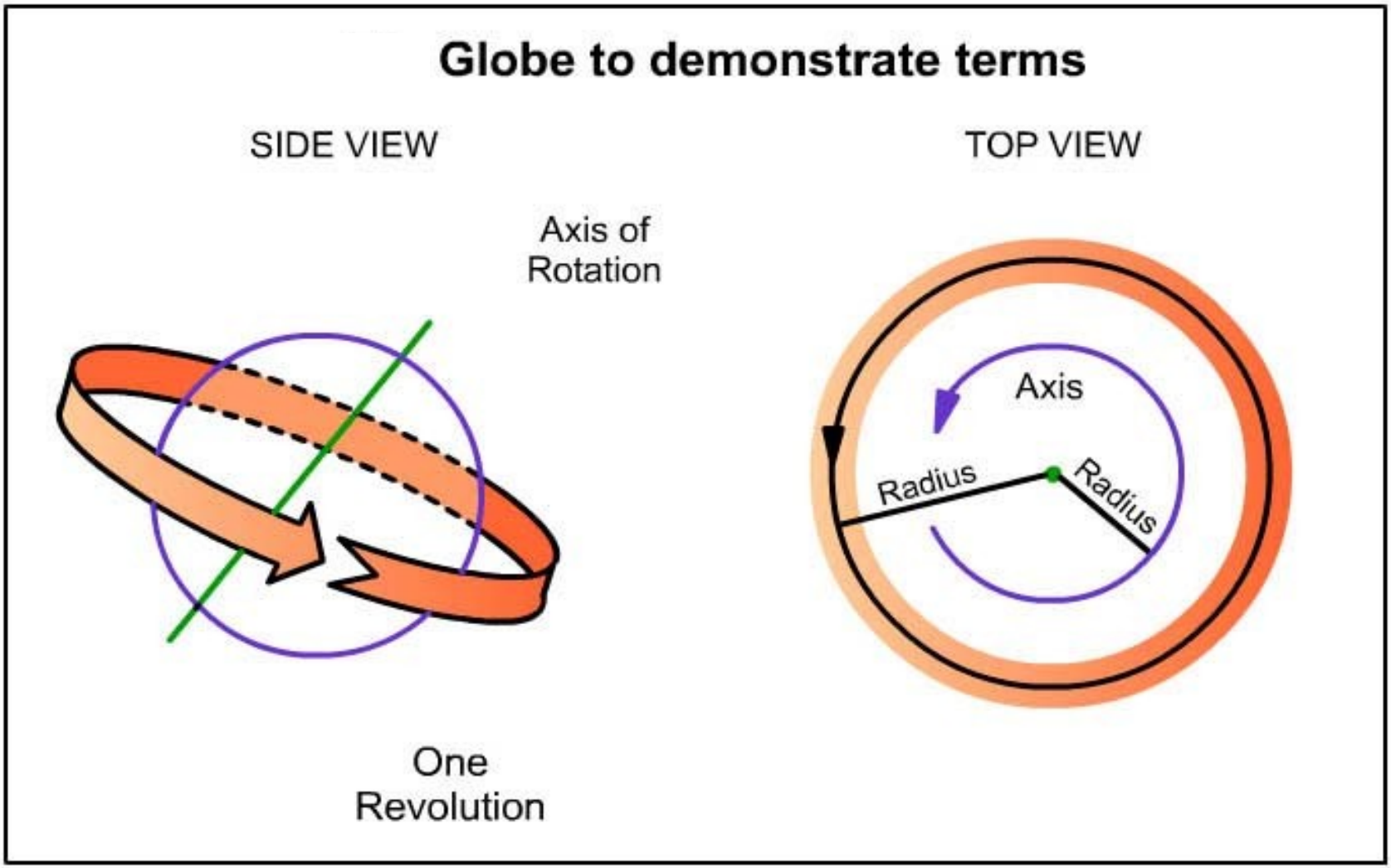
Atmospheric Dynamics I

1a. Determine the parameters of rotational and circular motion.

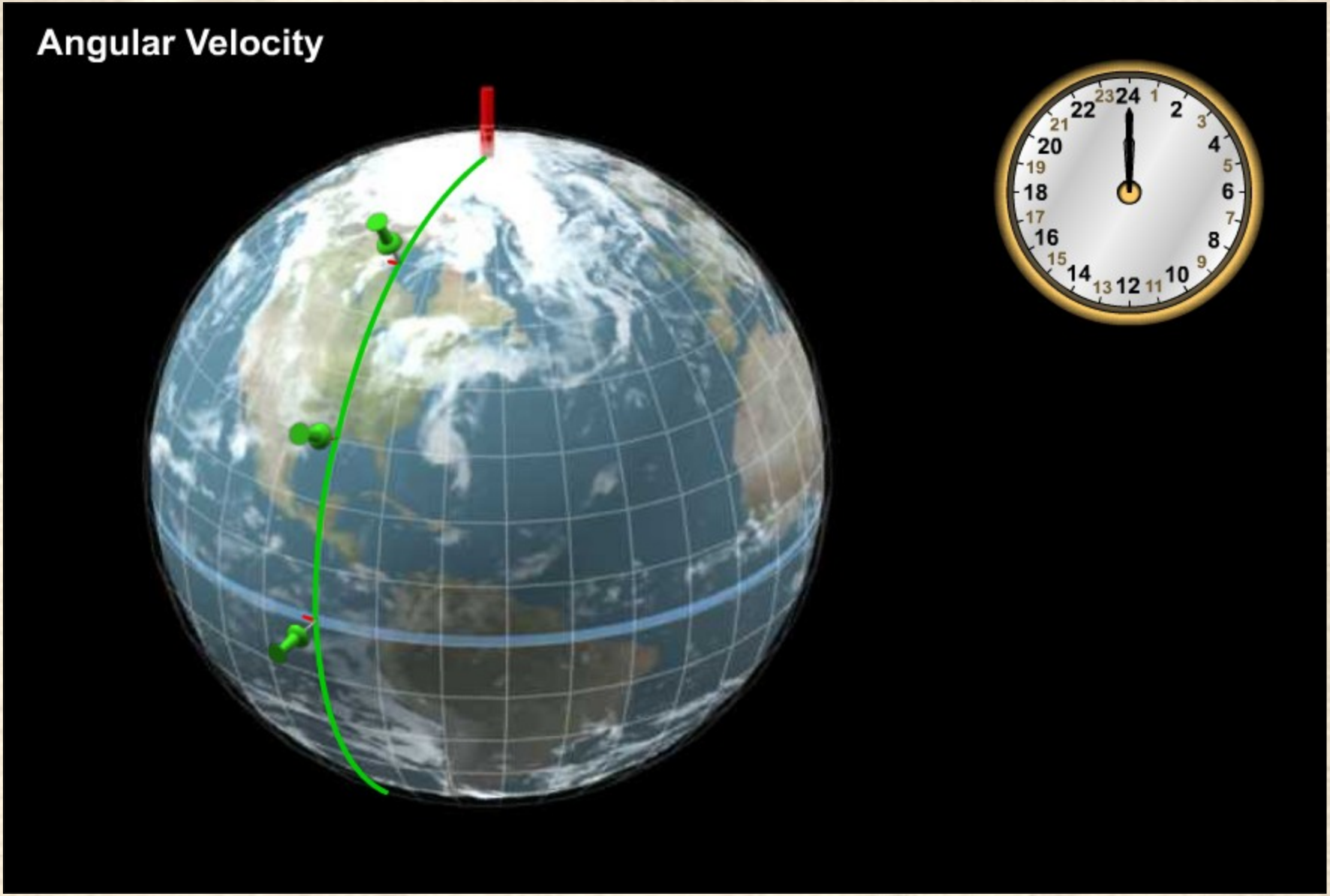
Definitions of Rotation

- Revolution (Rev) - One complete turn, 360° around a circle (or 2π radians (rad), where π = 3.14 . . .).
- Axis of rotation - Line about which a rotating body, such as the Earth, turns.
- Radius of rotation (r) - Distance from axis of rotation to edge of the circle.


Globe to demonstrate terms
SIDE VIEW
TOP VIEW
Axis of Rotation
Axis
Radius
Radius
One Revolution

Definitions of Rotation

- Angular Velocity (ϖ, omega) -
  - Represents rate of rotation about an axis of rotation
  - Measured in degrees or radians, per unit time.
  - For the Earth: denoted as Ω.
  - Examples:
    - The second hand of a clock (360°/60 sec or 2π rad / 60sec),
    - 45rpm records
    - The solid Earth (1 rev/day = 360°/24 hrs or 2π rad / 24 hrs)


Angular Velocity

Definitions of Rotation

- Angular velocity cont.
  - Every point on Earth has same angular velocity. Takes 24 hrs to complete one revolution no matter if you're standing at equator or 80° north latitude.

Definitions of Rotation

- Linear Velocity (V) Represents rate of displacement (distance/unit time) of a particle in a given direction. (Ex: 45 mph to the northeast)

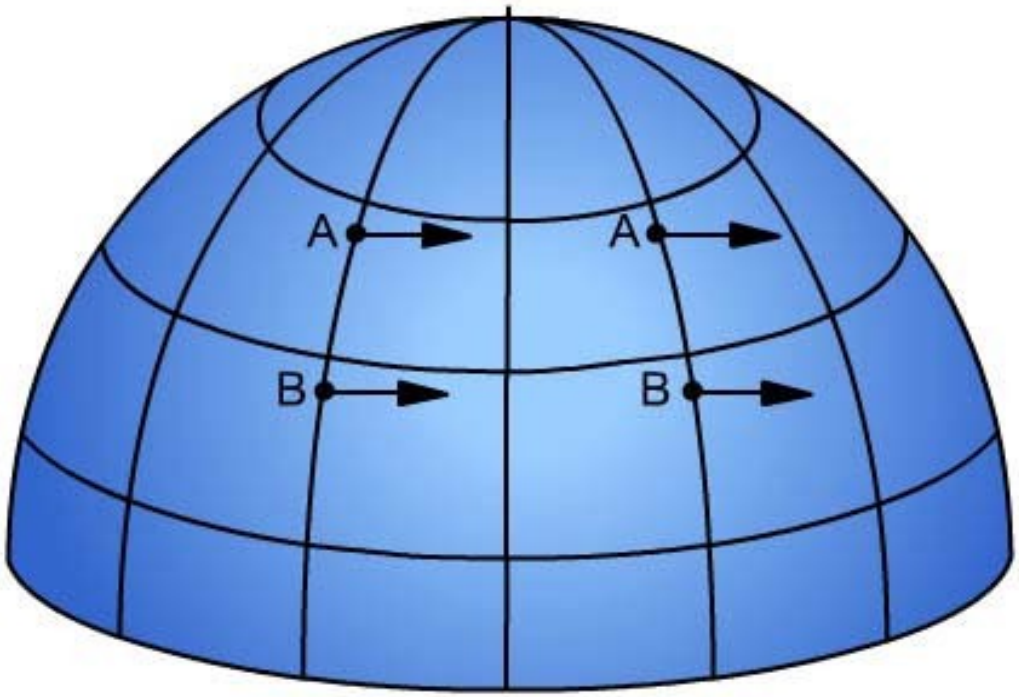
Lake Linear
Velo City, IN
98
88
3
9
271
3
88
98
3
233
9
88
233
3
9
3
88
24
98
244
9
88
71
271
99
910
910
910
244
24
99
22
71

Angular and Linear Velocity Relationships

- **For the solid Earth.**
  - Angular velocity (Ω)
    - is constant for every point on Earth.

    $\forall\Omega = 7.292 * 10^{-5}$ radians / second

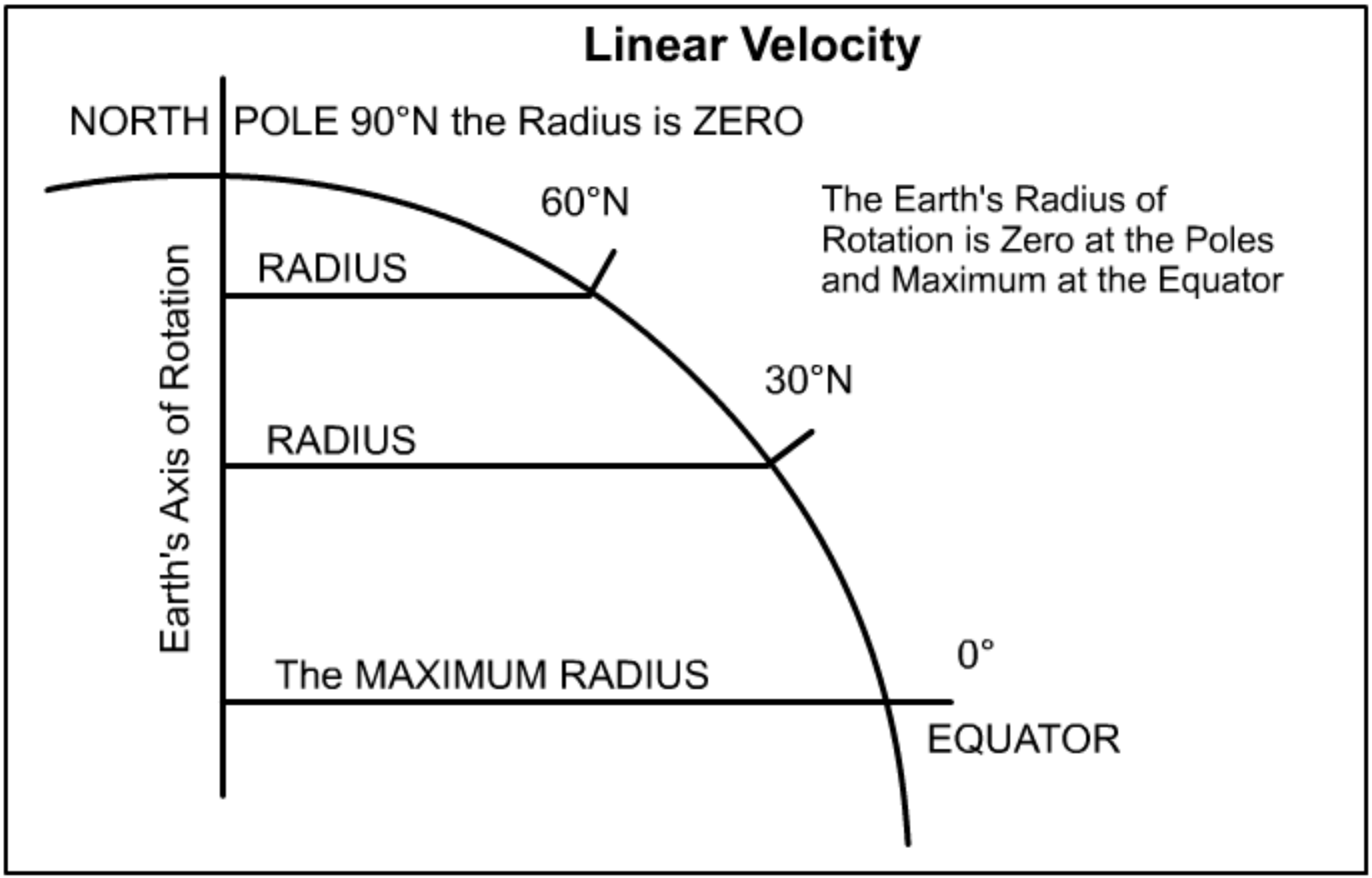
    $\forall\Omega$ of points "A" and "B" on TR = 1 rev/day.

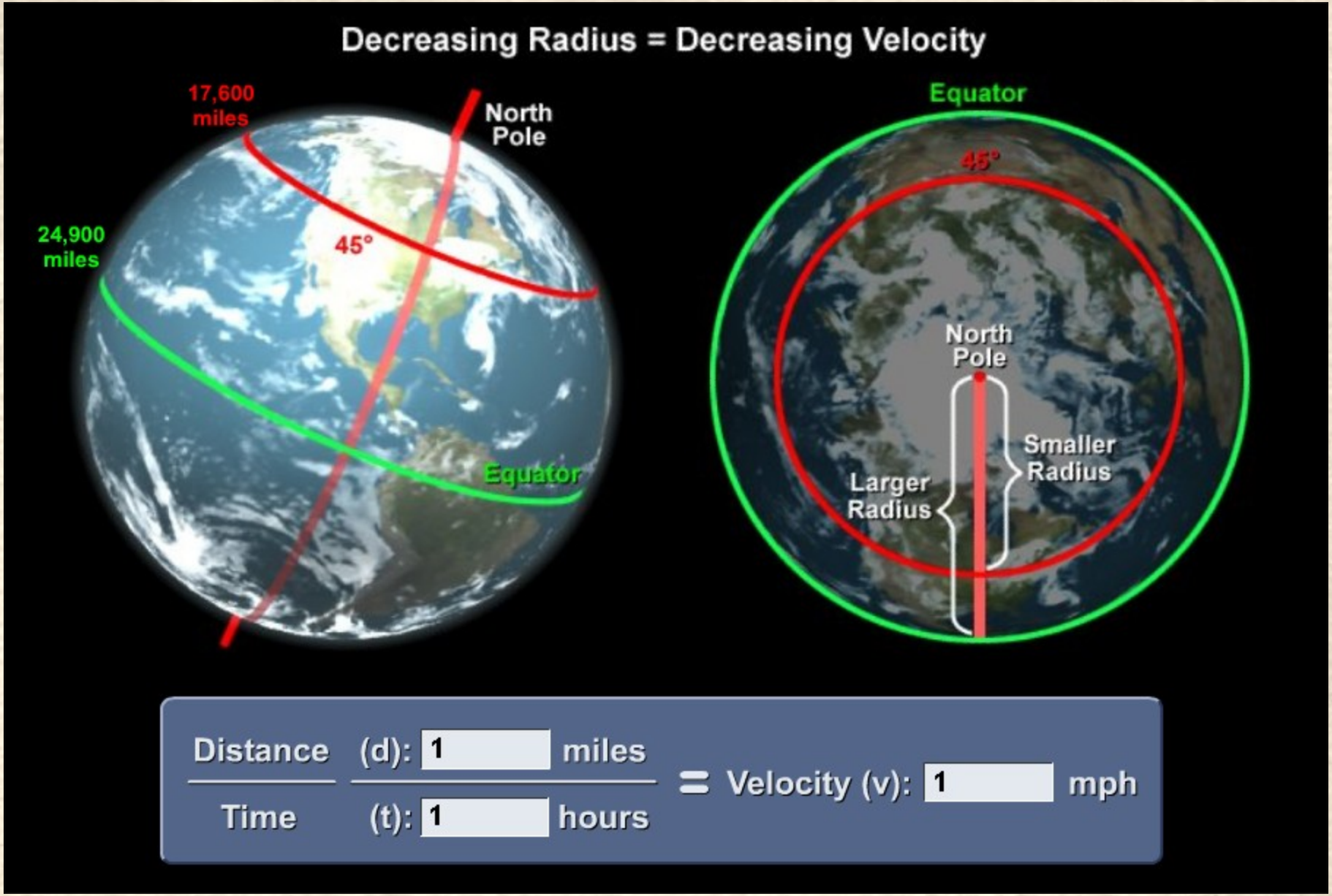


ANGULAR VELOCITY IS CONSTANT

Angular and Linear Velocity Relationships

- Linear velocity (V)
  - Varies as radius (r) changes.
  - Equation: $V = \Omega r$,
  - “V” directly proportional to “r”.
  - “r” decreases poleward, therefore increasing latitude = decreasing “r” = decreasing “V”.

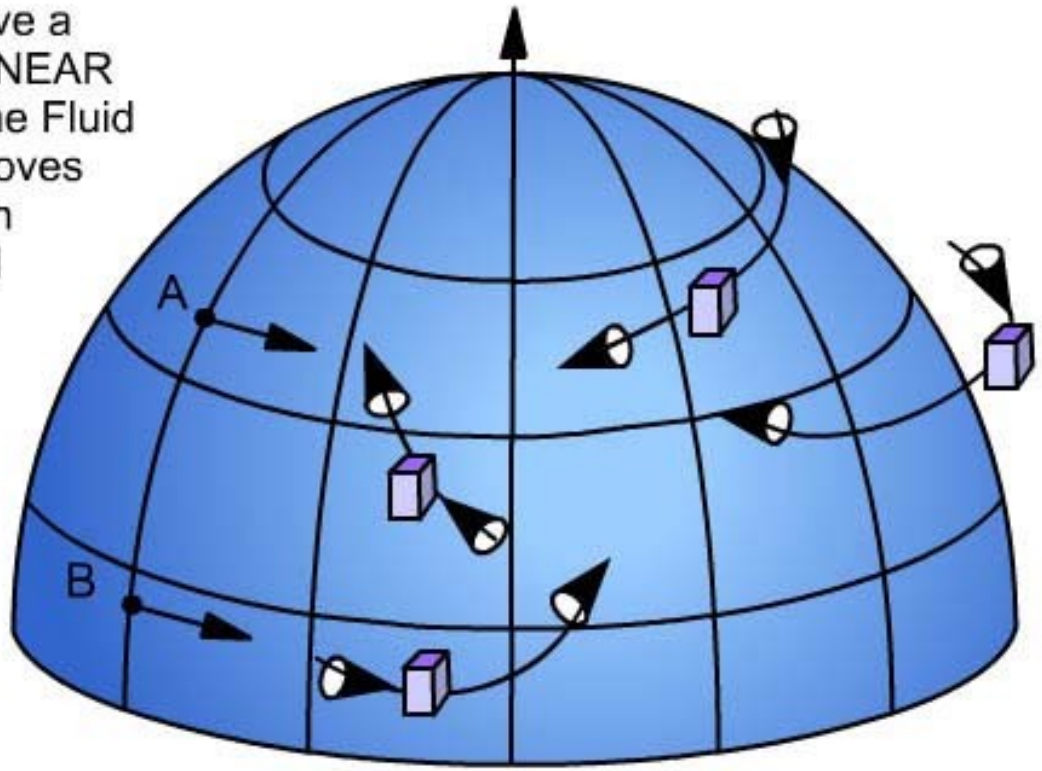

Linear Velocity
NORTH POLE 90°N the Radius is ZERO
60°N
The Earth's Radius of Rotation is Zero at the Poles and Maximum at the Equator
RADIUS
Earth's Axis of Rotation
30°N
RADIUS
0°
The MAXIMUM RADIUS
EQUATOR


Decreasing Radius = Decreasing Velocity
17,600 miles
North Pole
24,900 miles
45°
Equator
Equator
45°
North Pole
Smaller Radius
Larger Radius
Distance (d): 1 miles
Time (t): 1 hours
= Velocity (v): 1 mph

Angular and Linear Velocity Relationships

- **For the atmosphere (or ocean), and NOT the solid Earth**
  - Angular velocity (ϖ) ανδ λινεαρ ϖελοχιτψ (ϖ) αρε ϖαριαβλε
    - Atmosphere is a fluid
    - Does not rotate at same speed as Earth.
    - Fluid atmosphere can move faster, slower, poleward, or equatorward.

Points A+B Have a CONSTANT LINEAR VELOCITY. The Fluid Atmosphere Moves In Any Direction and Any Speed



Momentum

- Measure of Inertia
- Product of mass of object and its velocity
- Types:
  - Linear Momentum (LM)
    - Straight-line momentum

Momentum

- Linear Momentum cont.
  - Newton's First Law of Motion: - An object at rest tends to stay at rest and an object in motion tends to stay in motion at same velocity (be conserved) until acted on **by** an outside force.
  - Equation: **LM = mV**
- Angular Momentum (AM)
  - Momentum in curved flow
  - Product of LM and radius of rotation for an object or parcel.
  - Equation: **AM = LM x r , so AM = mVr**

Momentum

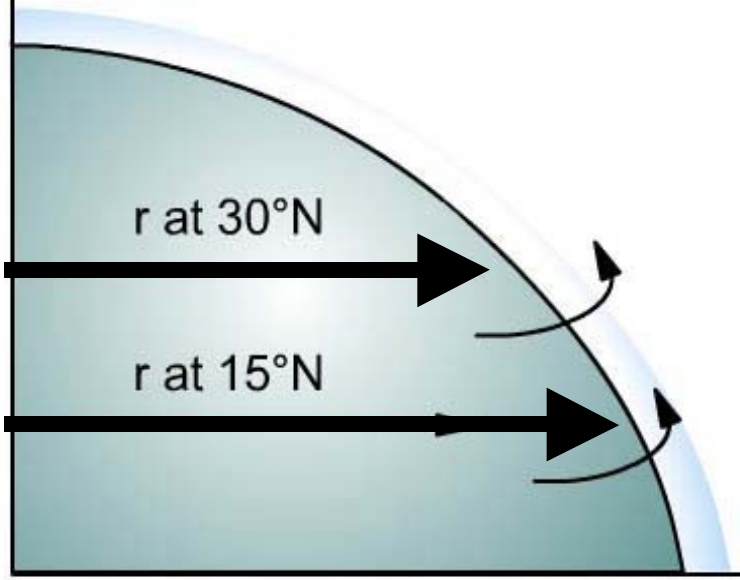
- Angular momentum cont.
  - AM is conserved for an object when forces acting upon the body are in balance.
  - If r decreases, and m is constant, then velocity must increase in order to conserve AM.
  - Examples:
    - An ice skater: When moving the arms from an extended position, large radius, to a tucked position, smaller radius, velocity increases, conserving the AM.
    - A ball on a string wrapped around a finger: As it spins the string wraps around the finger decreasing r, and increasing v.

Momentum

- Angular momentum cont.
  - The atmosphere, a fluid **not attached to the solid Earth, tries to conserve AM.**
    - As r decreases with an increase in latitude, V increases.
    - As r increases with a decrease in latitude, V decreases.
  - Application of AM. We will use the concept of conservation of angular momentum to help explain the changes in velocity that occur to air parcels in the atmosphere as they move poleward or equatorward, and their radius of rotation changes.

RELATIONSHIP OF AM TO THE EARTH AND ATMOSPHERE

ANGULAR MOMENTUM



AM=m**v**r
AM is conserved
m assumed constant

As an air parcel
moves from 15N to 30N
r↓so **V**↑

- APPLICATION: Throughout the entire lesson.
- EVALUATION: Written test at the end of the unit.